(12) UK Patent Application (19) GB (11) 2 017 592 A

(21) Application No 7910645
(22) Date of filing 27 Mar 1979
(23) Claims filed 27 Mar 1979
(30) Priority data
(31) 2814314
(32) 3 Apr 1978
(33) Fed. Rep. of Germany (DE)
(43) Application published
10 Oct 1979
(51) INT CL²
B63B 35/44
(52) Domestic classification
B7A 132 308 309 CA
(56) Documents cited
GB 1371147
GB 1277494
(58) Field of search
B7A
B7V
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(54) **Improvements in or Relating to Floating Storage Installations for Liquids**

(57) In a floating storage installation for liquids, particularly oil or liquefied natural gas from underwater fields, and comprising at least two reservoirs (1), a working platform (7) located above the storage reservoirs (1) and a ballasting system (3) whereby the buoyancy and weight of the installation can be balanced to ensure that the storage reservoirs (1) and the ballasting system (3) lie below the surface of the water, whilst the working platform (7) lies above it, both the working platform (7) and the reservoirs (1) are independently supported on the ballasting system (3). With such an arrangement, it is not necessary to provide shafts for access to the ballasting system passing through the storage reservoirs, which is undesirable, particularly when low temperature liquefied gas is being stored. Access to the ballasting system can be provided by shafts in columns (9) by which the platform (7) is supported on the ballasting system (3).

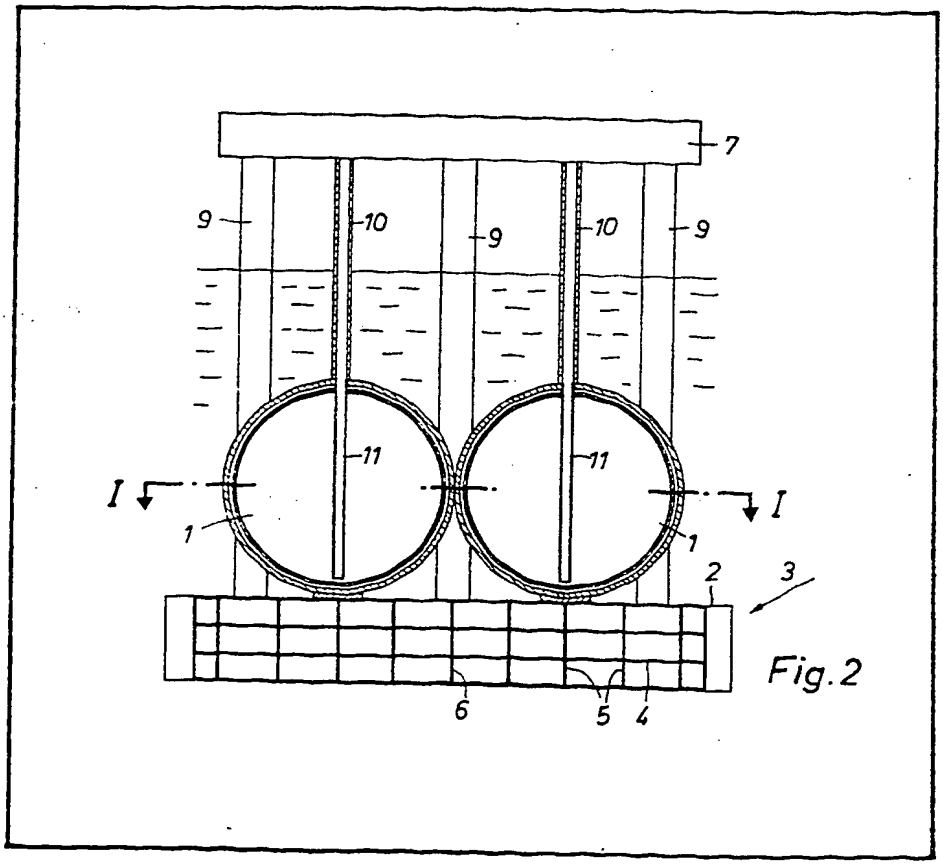

Fig.2

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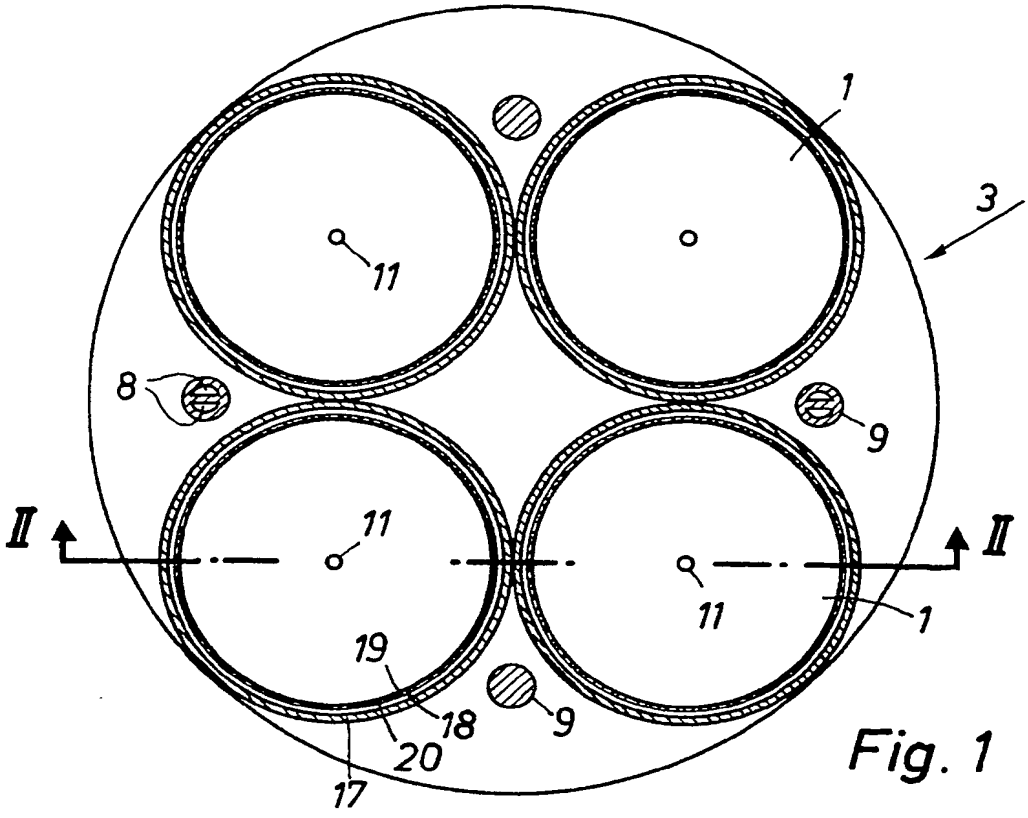

Fig. 1

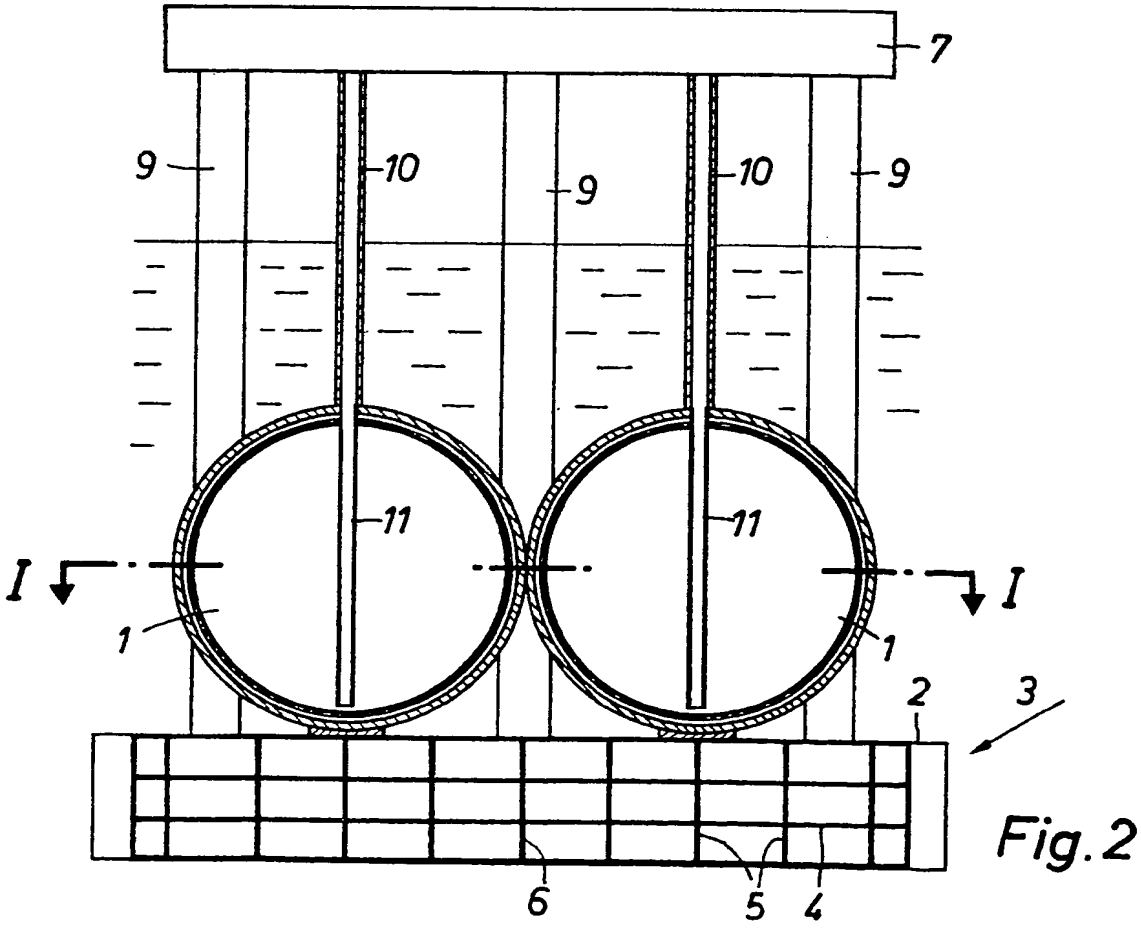

Fig. 2

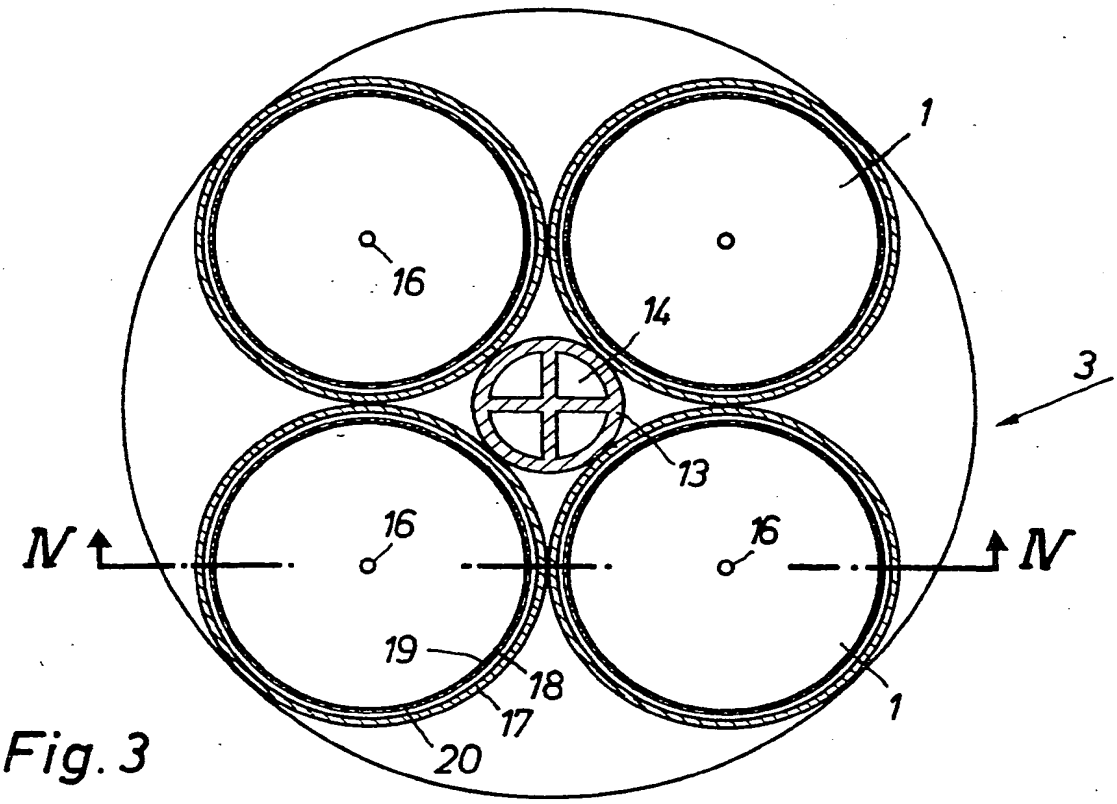

Fig. 3

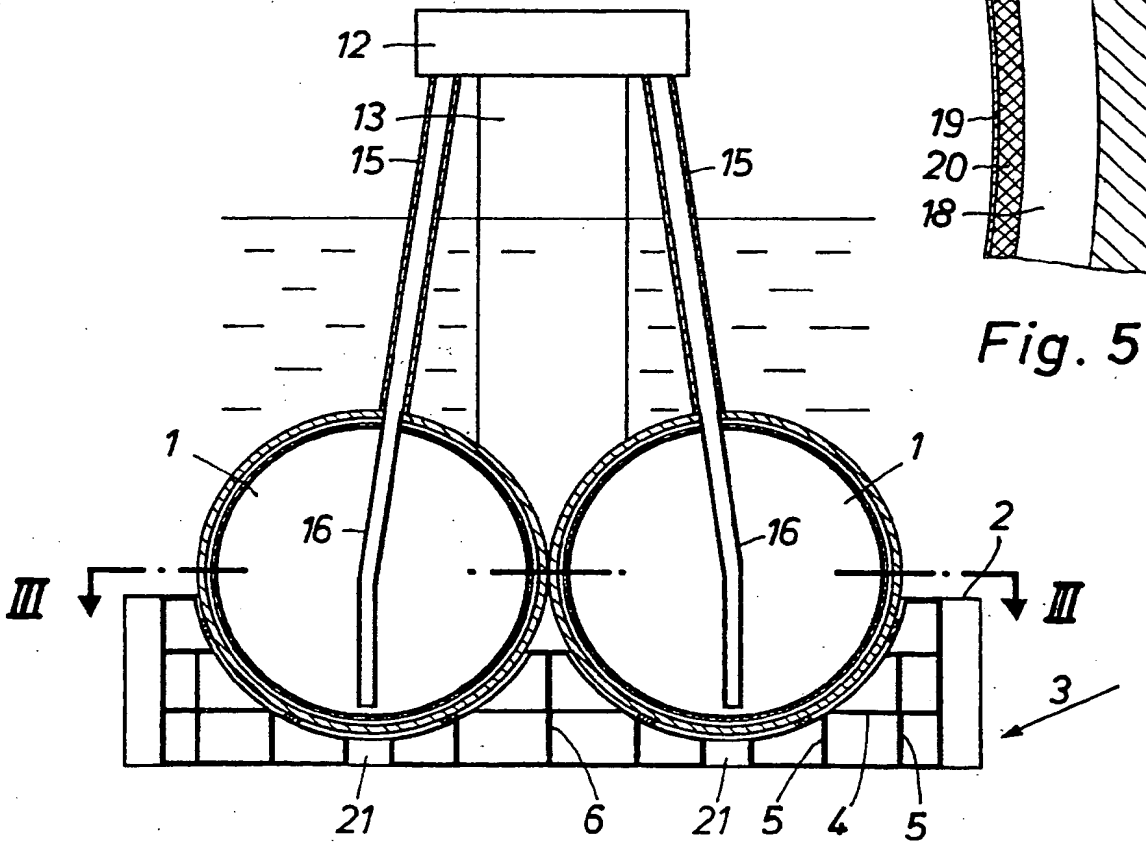

Fig. 4

Fig. 5

SPECIFICATION

Improvements in or Relating to Floating Storage Installations for Liquids

The present invention relates to a floating storage installation for liquids having at least two storage reservoirs, a ballasting system and working platform disposed above the storage reservoirs, in which installation when in use the buoyancy and the weight of the storage installation are so balanced one against the other by filling or emptying the ballasting system that the storage reservoirs and the ballasting system lie below the surface of the water in which the installation floats, while the working platform is located above it.

Floating liquid storage installations are required for temporary storage, for example, when tapping petroleum or natural gas fields in shelf or other maritime regions. In the case of natural gas storage, the gas has first to be liquefied. Such installations are also of value for long-term storage, if the construction of an underwater pipeline is undesirable for technical or financial reasons.

Storage installations of the kind referred to above are already known. They comprise storage reservoirs over which a working platform is erected. This is carried by one or more columns projecting from the water. A ballasting system is provided underneath the storage reservoirs.

One disadvantage of the known structures is that the ballasting system is only accessible from the working platform through shafts which pass through the storage space. This not only reduces the storage capacity, but, much more importantly, leads to increased structural requirements in the design of the storage reservoirs. This is disadvantageous, particularly when the reservoirs are for the storage of liquefied gases having low boiling points, since the thermal insulation needed for the storage reservoir in such cases is particularly costly owing to the increased internal surface area of the storage reservoir and the extra edges produced.

It is therefore an object of the present invention to provide a storage installation of the kind referred to above which allows optimum use to be made of the available storage capacity and has a very simple design.

According to the invention, there is provided a floating storage installation for a liquid comprising at least two storage reservoirs, a working platform located above said storage reservoirs and a ballasting system, by filling or emptying which the buoyancy and weight of the installation can be balanced in use to maintain the storage reservoirs and the ballasting system below the surface of the water and the working platform above it, wherein said working platform and said storage containers are each mounted independently of the other on the ballasting system.

The storage installation of the invention departs from the usual design principle in which the three elements, ballasting system, storage reservoir and working platform are built in stories one upon another. Instead the working platform is mounted directly on the ballasting system on which the storage reservoirs are also carried in the usual way, but independently of the working platform.

One great advantage of the storage installations in accordance with the invention resides in the fact that the storage reservoirs can be of simple construction. For example, spherical containers or cylindrical tanks of conventional type can be used, without the need to provide shafts passing through to the ballasting system located underneath the storage reservoirs. Instead, this system is directly accessible from the working platform.

In one favourable embodiment of the invention, each storage reservoir comprises a pressure-resistant outer wall within which is housed a tank of conventional design. The pressure-resistant design of the outer wall makes it possible to keep the interior of the storage reservoir at atmospheric pressure. This means that conventional tank designs that have proved themselves on land can be used for the storage reservoirs, resulting obviously in a reduction in the cost of production. Cylindrical, or preferably spherical, designs are suitable particularly for the tanks. The pressure-resistant outer wall is preferably shaped like the tank, in order not unnecessarily to increase the water displacement and thus the buoyancy of the storage installation. It is, however, advantageous to leave a space between the outer wall and the outer surface of the tank large enough for working personnel to move around in it. This allows easy inspection of the walls and of any tank insulation that may be required.

The space between the outer wall and the tank can be provided with a drainage system through which any water which may seep in through the outer wall can be pumped away.

Advantageously, the storage reservoirs are so arranged that their outer walls are essentially freely suspended and washed by the sea water in use. This has the advantage, particularly when storing liquids with low boiling points, that the outer walls are heated simply without any special equipment being required for this purpose.

In a preferred embodiment of the invention, the storage reservoirs each communicate with the working platform via a respective shaft. These shafts can run vertically or at an angle and open into the upper part of the storage reservoirs. They house the lines needed for charging and discharging the installation.

In addition, these shafts provide access to the pumps needed to move the liquid being stored. For this purpose, it is expedient if pipes run from the working platform right down to the vicinity of the bottom of the respective storage reservoirs. When the shafts run at an angle, as may be necessary with a small working platform if the shafts are to open into the upper parts of the

spherical tanks, it may also be expedient to bend the pipes in the lower part of the tank so that they terminate in a vertical portion. This has proved to be an advantage because the pumps used to move the fluid, which are advantageously immersion pumps, can stand vertically on the bottom of the tank when the pipes are disposed in such a way.

Since the working platform is built directly onto the ballasting system, the communicating shafts between the working platform and the storage reservoirs do not have to perform any supporting function for the working platform and consequently do not impose any appreciable loading on the storage reservoirs.

Advantageously, the ballasting system is divided into a plurality of ballast chambers. In this case, each storage reservoir preferably has one ballast chamber associated with it, which is coupled to the storage reservoir by means of a regulating arrangement. When the storage installation is being charged or discharged, the respective ballast chambers can be emptied or filled at the same time, thereby keeping the floating attitude unchanged throughout the charging or discharging period without it being necessary to charge or discharge all the storage reservoirs uniformly.

Within the individual ballast chambers, apertured supporting walls may be provided to give the structure the necessary rigidity.

Advantageously, the ballasting system is arranged to be accessible from the working platform through at least one pillar carrying the working platform. Within the pillar, a shaft or shafts is or are provided for this purpose, through which the pumps for the ballast water are accessible from the working platform by means of a lift arrangement. In addition, further shafts can be provided to give access to the ballasting system for working personnel.

In one advantageous embodiment, the ballasting system consists of a flat base section having closed outside walls and cavities within. The storage reservoirs and the working platform may be mounted on the upper horizontal surface of this structure.

Alternatively, storage reservoirs may be mounted, not directly on the horizontal outer face of the ballasting system, but instead the upper surface of the ballasting system is provided with recesses into which the bottoms of the storage reservoirs fit. With such an arrangement, the ballast chambers are disposed partly under and partly around the storage reservoirs. Consequently, the draught of the whole installation can be reduced without reducing the capacity of the storage reservoirs or of the ballast chambers.

Storage installations in accordance with the invention are particularly advantageous for the storage of liquefied gases having low boiling points. The advantages obtained through the construction of the invention are especially obvious in such an application. The surface of the storage reservoirs can be simply provided with conventional thermal insulation without any need for the provision of additional insulation for shafts running through the storage reservoirs to the ballasting system. In addition, another problem arising with previously known arrangements, that is the heating of walls exposed to low temperatures, does not arise at all. In the known arrangements, an expensive heating system has to be provided to ensure that the walls, which are usually made of concrete, do not fall to temperatures at which the strength of the structure is jeopardised. In fact, when the storage reservoirs have good thermal insulation, such cooling cannot be completely prevented. However, with the installations of the invention only the outer walls of the reservoirs will be cooled by the inevitable cold losses. However, these are washed with sea water and thus constantly kept at ambient temperature. Inside the storage reservoirs there are no walls whatsoever that require to be heated.

The size of the ballasting system may be arranged to be such that the storage installation will rest on the sea bottom, regardless of its state of loading. In such circumstances, which are only possible however when the water is not too deep, a stable attitude is achieved for the storage installation, so that there is no need for any trimming using the ballasting system when charging or discharging.

The invention will now be further described with reference to the drawings, in which:—

Figure 1 is a schematic sectional plan view of a storage installation in accordance with the invention, taken along the line I—I of Figure 2;

Figure 2 is a vertical section taken along the line II—II of Figure 1;

Figure 3 is a schematic sectional plan view of another storage installation in accordance with the invention, taken along the line III—III of Figure 4;

Figure 4 is a section taken along the line IV—IV of Figure 3; and

Figure 5 is a scrap side section through the wall of a storage reservoir and of a tank of either of the storage installations of Figures 1 to 4, on an enlarged scale.

Figures 1 and 2 illustrate a storage installation for liquefied natural gas which is provided with four spherical storage reservoirs 1. The storage reservoirs 1 are mounted on the horizontal surface 2 of a disc-shaped hollow base 3.

The interior of the base 3 is provided with horizontal and vertical bracing walls 4 and 5 respectively, which ensure the rigidity of the structure. Within the base 3, the ballasting system for the storage installation is housed. To allow filling and emptying of the ballast chambers, the bracing walls 4 and 5 are provided with ports to allow ballast water to pass through them. In addition, vertical walls 6 without ports are provided to divide the interior of the base into separate ballast chambers. The dividing walls 6 are so arranged that the circular disc-shaped base

3 is divided into four sectors each of which lies underneath a respective one of the storage reservoirs 1.

The individual ballast chambers of the ballasting system are accessible from a working platform 7 through shafts 8. The shafts 8 run in vertical pillars 9 by means of which the working platform 7 is mounted on the base 3 so as to be above the surface of the water in use. By erecting the pillars above the dividing wall 6 between two ballast chambers, access is given to the two separate ballast chambers through two shafts 8 inside one pillar 9 in each case.

On the working platform 7, there is located a transfer system (not shown) by means of which the stored liquid natural gas can be discharged into tankers. The working platform 7 also carries plant for preparing and liquefying the natural gas, accommodation for working personnel, a helicopter landing pad and other necessary equipment, none of which is shown.

The storage reservoirs 1 are accessible from the working platform 7 through vertical shafts 10. Inside the shafts 10, lines are provided for taking on and discharging liquefied natural gas, and also gas lines. In addition, the immersion pumps required in the reservoirs to move the stored liquid can be brought up to the working platform 7 or replaced in the storage reservoirs 1 by means of a hoist provided within the shaft 10, for the purpose of repair or maintenance. To ensure safe guidance of the immersion pumps, the shafts 10 inside the storage reservoirs 1 are extended by means of shafts 11 which terminate in the vicinity of the bottoms of the storage reservoirs. Whereas the shafts 10 are made of concrete and are pressure-resistant, the shafts 11 inside the storage reservoirs 1 are made of a material which is resistant to low temperatures.

Figures 3 and 4 show another instllation in accordance with the invention which is intended to serve as a temporary reservoir for liquefied natural gas. For this reason, only a few structures are required on the working platform 12, basically just a transfer system for discharge to tankers and the installations needed for filling and emptying the storage reservoirs 1. Consequently, the working platform 12 can be considerably smaller than in the embodiment illustrated in Figures 1 and 2. It is supported on the base 3 by means of a central pillar 13 in which communicating shafts 14 between the working platform 12 and the ballasting system in the base 3 are provided.

Apart from this, this installation differs from that shown in Figures 1 and 2 in the design of the base section 3. On its upper surface this is provided with dish-shaped recesses which are shaped to receive the lower ends of the spherical storage reservoirs 1. Consequently, the ballast chambers are not just disposed under the storage reservoirs 1 as in the embodiment of Figures 1 and 2, but also lie partly around them. This design for the base 3 has the advantage of reducing the total draught of the storage installation. In order to prevent the areas of the walls of the storage reservoirs 1 which lie inside the recesses from cooling, a space is provided between the surface of the base 3 and the outside of the storage reservoirs 1, through which sea water is arranged to flow, as a result of which the wall of the storage containers 1 is kept at ambient temperature at all times. To ensure adequate cooling of the wall, a duct 21 is provided in the lowermost part of the recess through which the water can flow out downwardly. This has the result that cooled water flows away on its own because of its higher specific gravity, without there being any need to take special steps to ensure this.

Such a design for the base 3 is also advantageous as regards the mounting of the storage reservoirs 1, since this is achieved at a number of points within the dish-shaped recesses and not just at the point of contact of the bottom point of the reservoir with the base 3 as in the embodiment of Figures 1 and 2.

The storage reservoirs 1 are accessible from the working platform 12 through shafts 15 running at an angle to the vertical. Within the storage reservoirs 1, the shafts 15 are extended down to the vicinity of the bottom of the storage reservoirs 1 by respective shafts 16 made of a material that can withstand low temperatures. To ensure favourable location of the immersion pumps when they are introduced into the storage reservoirs 1 throught the shafts 15 and 16, the shafts 16 are bent so that they terminate in a vertical portion.

For a capacity of 125,000 cubic metres, the storage reservoirs 1 of the installations in accordance with the invention would consist of four spherical tanks, each with an internal diameter of 40 metres. Figure 5 shows a section through a part of the wall structure of such a storage reservoir 1. The wall structure consists of a 1 metre-thick pressure-resistant outer wall 17 made of concrete which bounds an inner space 18 some 0.75 metres wide within which personnel can move. This space is accessible to personnel, so that the pressure-resistant wall 17 can be inspected even while the installation is in service. Water seeping in through the wall 17 is collected by a drainage system and discharged again by means of a pump (not shown).

The wall 19 of the spherical tank is made of a metal that can withstand low temperatures and is provided with a 25 cm-thick layer of thermal insulation 20 on its exterior. The tank can be mounted in the outer wall of the storage reservoir 1 in conventional manner, for example, by placing it on a circular carrier which is fixed roughly level with the point of maximum horizontal cross-section of the tank.

Claims

1. A floating storage installation for a liquid, comprising at least two storage reservoirs, a working platform located above said storage reservoirs and a ballasting system, by filling or emptying which the buoyancy and weight of the

installation can be balanced in use to maintain the storage reservoirs and the ballasting system below the surface of the water and the working platform above it, wherein said working platform and said storage containers are each mounted independently of the other on the ballasting system.

2. A storage installation as claimed in Claim 1, wherein each storage reservoir comprises an internal storage tank surrounded by a pressure-resistant outer wall spaced therefrom.

3. A storage installation as claimed in Claim 1, wherein said storage reservoirs are spherical.

4. A storage installation as claimed in Claim 3, as dependent on Claim 2, wherein both the outer walls and the tanks of said storage reservoirs are spherical.

5. A storage installation as claimed in any one of the preceding Claims, wherein the outer walls of the storage reservoirs are essentially freely suspended and are kept at the desired temperature in use by sea water.

6. A storage installation as claimed in any one of the preceding Claims, wherein each storage reservoir communicates with the working platform through a respective shaft.

7. A storage installation as claimed in any one of the preceding Claims, wherein the ballasting system comprises a plurality of ballast chambers; and wherein each storage reservoir is associated with a respective ballast chamber through a regulating system such that when one of said storage reservoirs is emptied or filled, the ballast chamber associated therewith is simultaneously filled with ballast water or emptied respectively.

8. A storage installation as claimed in any one of the preceding Claims, wherein the ballasting system is accessible from the working platform through at least one pillar supporting the workpiece platform.

9. A storage installation as claimed in any one of the preceding Claims, wherein the ballasting system is disposed within a base having a horizontal upper surface on which the reservoirs are directly mounted.

10. A storage installation as claimed in any one of Claims 1 to 9, wherein the ballasting system is disposed inside a base having recesses in its upper surface to receive said reservoirs, whereby the ballasting system surrounds the lower part of said reservoirs.

11. A floating storage installation substantially as hereinbefore described with reference to and as shown in Figures 1 and 2, or Figures 2 and 3, and Figure 5, of the drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1979. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.